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Status and Trends of Sea Otter Populations in Southeast Alaska, 1969–2003



Scientific Investigations Report 2009-5045

Cover: Sea otters resting in Barry Arm, Prince William Sound, Alaska, typical of groups observed during aerial surveys in Southeast Alaska. (Photograph courtesy of Jennifer Coffey, private citizen, July 29, 2008.)

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By George G. Esslinger and James L. Bodkin

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Scientific Investigations Report 2009–5045

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2009

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Suggested citation:

Esslinger, G.G., and Bodkin, J.L., 2009, Status and trends of sea otter populations in Southeast Alaska, 1969–2003: U.S. Geological Survey Scientific Investigations Report 2009–5045, 18 p.

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Conversion Factors and Datums

Conversion Factors

	Multiply	By	To obtain
kilometer (km)		0.6214	mile (mi)
kilometer (km)		0.5400	mile, nautical (nmi)
meter (m)		3.281	foot (ft)
meter (m)		1.094	yard (yd)
square kilometer (km ²)		0.3861	square mile (mi ²)

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Status and Trends of Sea Otter Populations in Southeast Alaska, 1969–2003

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Abstract

Aerial surveys of all known sea otter (*Enhydra lutris*) habitat in Southeast Alaska (SE AK) in 2002–2003 indicated a population size of 8,949 otters [Standard Error (SE) = 899] at an average density of 0.92 otters per square kilometer. These findings on sea otter distribution and abundance were compared to results from several previous surveys. Sea otters have expanded their range beyond the outer coast of SE AK and currently occupy inside waters such as Glacier Bay and Sumner Strait. This range expansion, along with archeological evidence, supports the hypothesis that sea otters are capable of colonizing inside waters in SE AK. Inside Glacier Bay National Park and Preserve, in northern SE AK, sea otter abundance has increased from 5 in 1995 to 1,266 (SE = 196) in 2002, more than doubling on an average annual basis, indicating immigration and reproduction as factors contributing to population growth. In the remainder of northern SE AK, the estimated abundance has declined from 2,295 in 1987 to 1,838 (SE = 307) in 2002. In southern SE AK, the abundance of sea otters increased from 2,167 in 1988 to 5,845 (SE = 821) in 2003. Overall, population growth rates for sea otters in SE AK between 1987 and 2003 are much lower than rates from previous studies and were unexpected given the amount of unoccupied habitat available in SE AK. Divergent population trajectories were evident between the southern (6.6 percent per year) and northern areas of SE AK (2.0 percent per year). These differences suggest variation in reproductive or survival rates between the areas. Harvest levels between 1989 and 2003 may have had a measurable effect on sea otter populations in SE AK. Available data on age and sex specific fecundity and survival rates could be used to develop age- and sex-structured population matrix models to help guide management and conservation of sea otter populations.

Introduction

Prior to the mid-1700s, sea otters occupied nearshore coastal waters in the Pacific Ocean from central Baja California to northern Japan, including both sides of the Alaska Peninsula and the Aleutian Archipelago

(Kenyon, 1969). Commercial fur harvests between 1741 and 1911 reduced sea otters to 13 small remnant colonies, mostly in the Aleutians, with the species extirpated between Prince William Sound, Alaska, and Central California (Riedman and Estes, 1990).

Between 1965 and 1969, the Alaska Department of Fish and Game translocated 403 sea otters from Prince William Sound and Amchitka Island to 6 areas along the outer coast of Southeast Alaska (SE AK) (fig. 1; table 1). Consequently, sea otters in SE AK contain a genetically diverse mixture of mitochondrial DNA from their source populations (Bodkin and others, 1999) and are considered to be a separate stock from southcentral and southwestern Alaska stocks based on genotypic differences and geographic distribution (Gorbics and Bodkin, 2001).

Since the translocations, sea otters have been surveyed in SE AK using various types of boats and aircraft (Schneider, 1975; Jameson and others, 1982; Johnson and others, 1983; Simon-Jackson and Hodges, 1986; Pitcher, 1989; Agler and others, 1995; and this study). In conjunction with the results of his 1987 and 1988 boat-based surveys, Pitcher (1989) provided a complete synthesis of SE AK sea otter surveys conducted through 1988. Prior to 1994, sea otter surveys were essentially censuses or minimum counts made from small vessels or from shore, and did not incorporate detection probabilities (Udevitz and others, 1995) or provide estimates of precision. In 1994, the U.S. Fish and Wildlife Service (USFWS) conducted boat-based marine bird and sea otter surveys throughout SE AK using strip-transect sampling methods and provided the first estimates of precision associated with a population survey of sea otters in the region (Agler and others, 1995). Beginning in 1999, the National Park Service (NPS) funded annual sea otter aerial surveys in Glacier Bay National Park and Preserve (Bodkin and others, 2007). Sea otter counts and locations also were recorded by USFWS (J. Hodges, U.S. Fish and Wildlife Service, written commun., 2002) during aerial waterfowl surveys in SE AK from 1997 to 2002.

The cumulative results of surveys of sea otters in SE AK and other translocated populations show that, due to mortality and emigration, translocated populations grow slowly during the first decade post translocation (Schneider, 1975; Bodkin and others, 1999), but increase over time (Pitcher, 1989).

2 Status and Trends of Sea Otter Populations in Southeast Alaska, 1969–2003

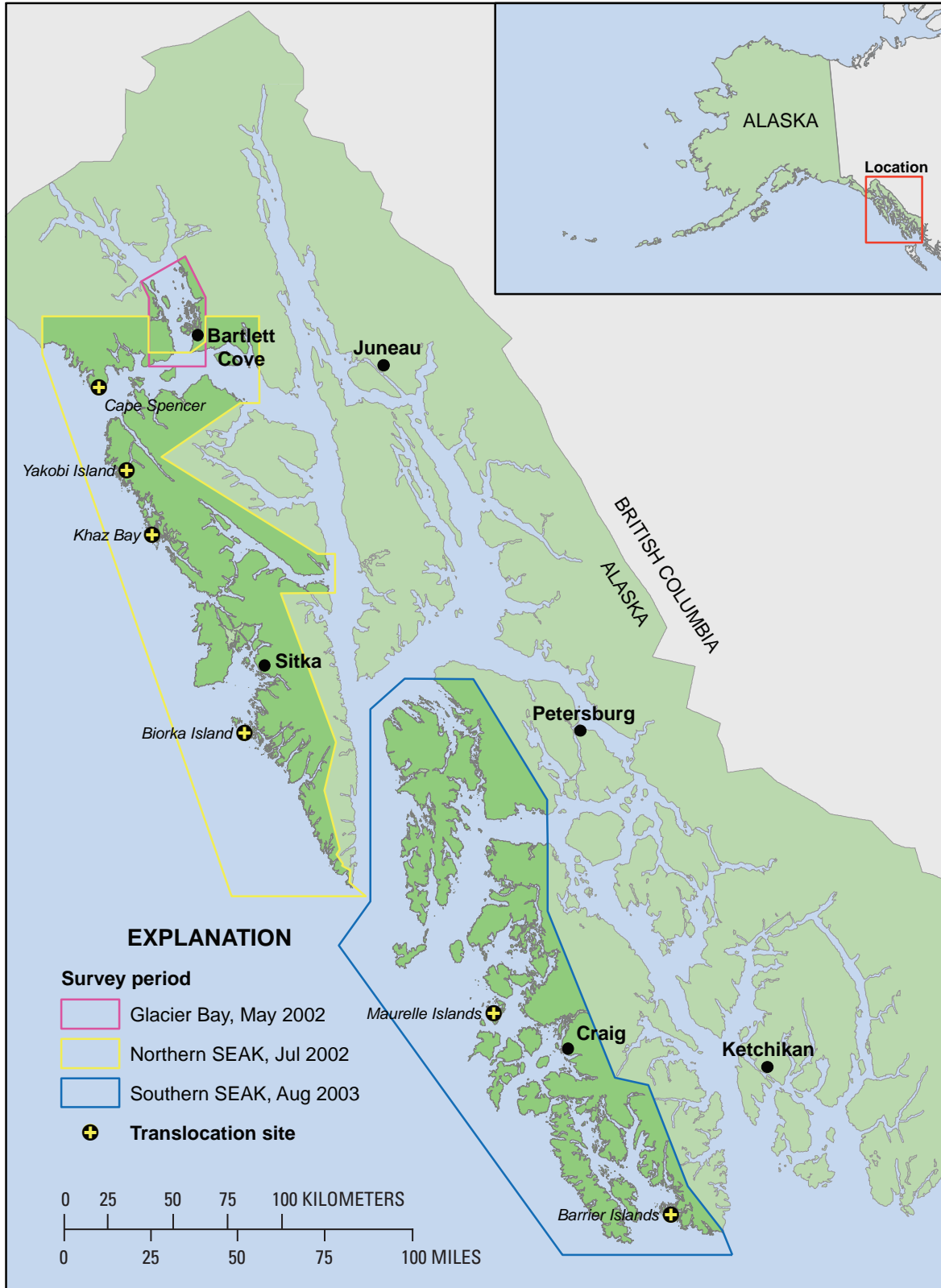


Figure 1. Sea otter translocation sites (1965–69) and areas surveyed for sea otters, Southeast Alaska (SEAK).

Table 1. Numbers of sea otters translocated to Southeast Alaska, 1965–1969.

[Data from Burris and McKnight, 1973]

Release site	Year					Total
	1965	1966	1967	1968	1969	
Cape Spencer	0	0	0	25	0	25
Yakobi Island	0	0	0	30	0	30
Khaz Bay	23	20	0	93	58	194
Biorka Island	0	0	0	48	0	48
Maurelle Islands	0	0	0	51	0	51
Barrier Islands	0	0	0	55	0	55
Total	23	20	0	302	58	403

Population growth rate estimates for sea otters in SE AK between 1975 and 1988 ranged from 16 to 23 percent (Pitcher, 1989) and were among the highest reported for expanding sea otter populations (Estes, 1990). During this period, sea otters expanded their range considerably and reoccupied large areas, primarily along the outer coast of SE AK (Pitcher, 1989).

The well documented overharvesting of sea otter populations demonstrates the need to monitor population status and trends for conservation and management (Kenyon, 1969). Because otters are harvested in much of their range in Alaska, conservation and management needs dictate careful evaluation of population status, trends, and harvest. Large-scale sea otter mortality events such as the Exxon Valdez oil spill (Estes, 1991) and the Aleutian sea otter decline (Doroff and others, 2003) underscore the importance of having current distribution and abundance data on sea otter populations. Recently, a series of aerial surveys have been conducted to assess the abundance of sea otters throughout their range in Alaska. The survey areas included Prince William Sound, Kenai/Cook Inlet, the Aleutian archipelago, Kodiak, and the Alaska Peninsula (Bodkin and others, 2002; J. Bodkin, U.S. Geological Survey, written commun., 2002; Doroff and others, 2003; U.S. Fish and Wildlife Service, unpub. data, 2004; and Burn and Doroff, 2005). Lacking recent population data for sea otters in SE AK, the U.S. Geological Survey (USGS) designed and conducted the first comprehensive aerial survey of sea otters in SE AK.

Methodology designed specifically to correct for detection (Bodkin and Udevitz, 1999) was used to conduct an aerial survey of sea otters in SE AK with the goal of obtaining accurate and precise population estimates. In this report, we present the results of three aerial surveys encompassing all habitats known to be occupied by sea otters in SE AK during the summers of 2002 and 2003 (fig. 1). We then compare the results of our surveys with prior boat-based censuses for all of SE AK to evaluate trends in sea otter abundance since the end of the translocations in 1969.

Study Methods

We used a strip transect aerial survey method that incorporated intensive searches to determine an observer and survey specific correction factor for diving sea otters and sightability bias (Bodkin and Udevitz, 1999). The survey areas were stratified based on depth and distance from shore, and transect spacing was varied within strata to match the sampling effort with expected sea otter densities (Bodkin and Udevitz, 1999; Bodkin and others, 2004). Because of the large geographic area involved, separate surveys were designed for three regions: (1) Glacier Bay, (2) northern SE AK, and (3) southern SE AK (fig. 1).

Glacier Bay

The survey in Glacier Bay was designed to ensure consistency with previous surveys conducted by USGS (Bodkin and others, 2007). The 2002 survey comprised five replicate aerial surveys with randomly selected combinations of high- and low-density stratum transects that varied among replicates (fig. 2). Transects in the high density stratum were spaced at what was considered maximum intensity (1,200 m) to increase precision of the population estimate while minimizing the probability of double-counting moving animals. For each replicate survey, approximately 67 percent of the sampling effort was allocated to the high-density stratum and 33 percent to the low-density stratum.

Northern and Southern Southeast Alaska

Designing an aerial survey for estimating sea otter abundance in SE AK required some understanding of their distribution. Approximate sea otter distribution in SE AK was determined by reviewing results of previous surveys (Simon-Jackson and Hodges, 1986; Pitcher, 1989; Agler and others, 1995; Garza and Lorrigan, 1999) and by consulting with local biologists, researchers, sea otter hunters, and nature tour operators. The selected survey area boundaries included all areas where groups of sea otters were known to occur or could easily emigrate. Areas where sea otter sightings were rare or where distances of sightings from known occupied habitat were great (for example, Juneau and Skagway) were not included. Excluding Glacier Bay, the survey area included 12,994 km of shoreline (fig. 1).

The SE AK surveys were modeled on the basis of earlier aerial designs used for surveying sea otters in Prince William Sound, Glacier Bay, Cook Inlet, Kenai Peninsula, and Kodiak Island waters (Bodkin and Udevitz, 1999; Bodkin and others, 2002; J. Bodkin, U.S. Geological Survey, written commun., 2002).

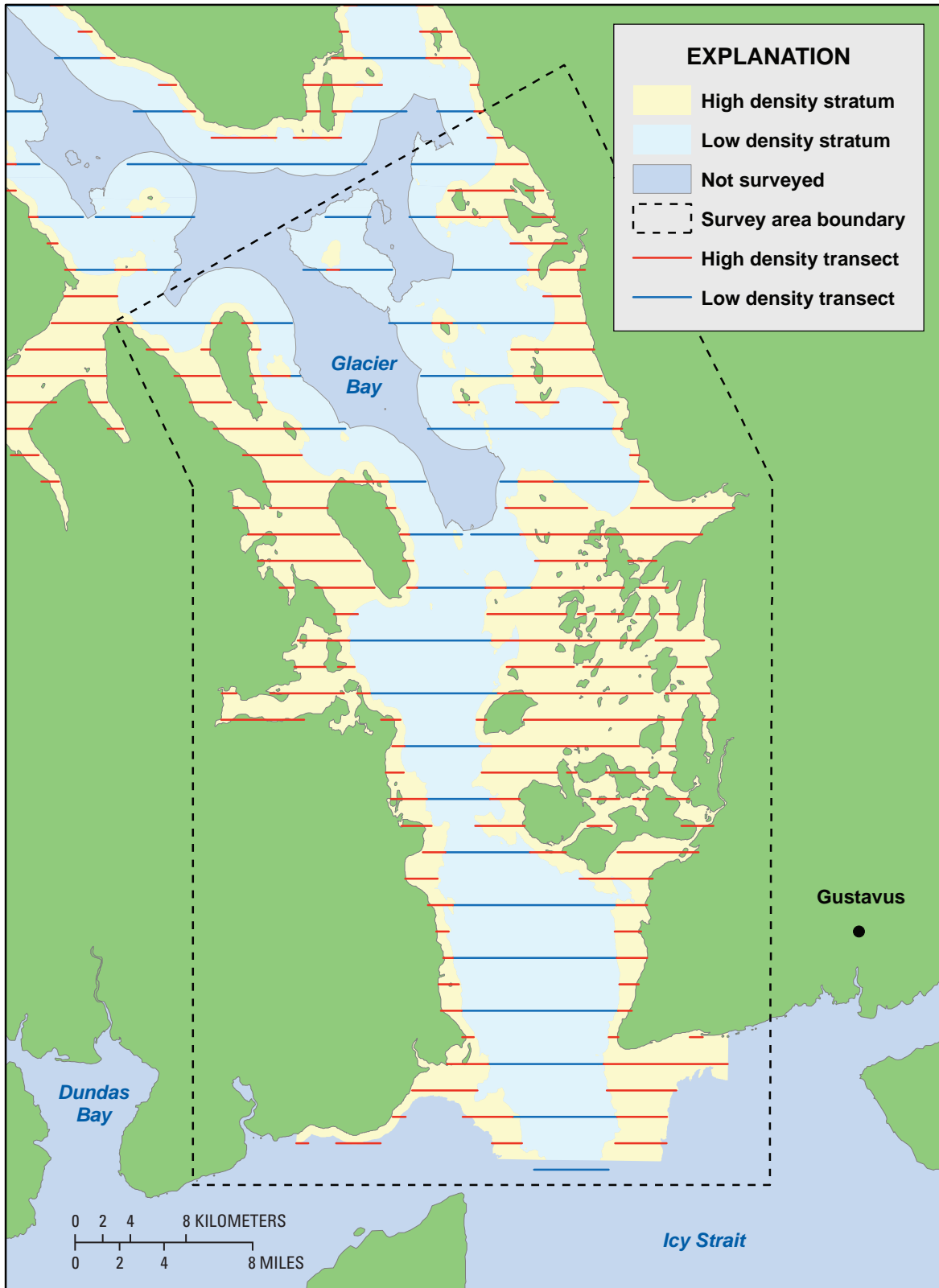


Figure 2. One of five replicate aerial surveys used to estimate sea otter abundance in Glacier Bay, Alaska, May 2002.

These surveys were developed with the aid of geographic information system software (ArcView and ArcInfo, ESRI, Inc. Redlands, Calif.) and required environmental data such as shoreline and water depth in digital format. Depth is a key variable in the creation of survey strata and, at the time of survey design, large sections of SE AK lacked digital bathymetric coverage. These digital data gaps made it necessary to digitize the 20- and 50-fathom depth contours from georeferenced digital images of National Oceanic and Atmospheric Administration (NOAA) nautical charts (Maptech, Amesbury, Mass.) using ArcView. Although digital shoreline data were available from several sources, those data matched the bathymetry poorly. Consequently, we also digitized the high-tide line from digital NOAA nautical charts. We used existing digital bathymetric data for Glacier Bay and part of Sumner Strait.

The northern and southern SE AK area transects were designed to be flown without replication due to logistical constraints. We allocated our sampling effort based on earlier testing (Bodkin and Udevitz, 1999), focusing 84 percent of our effort in the high density stratum and 16 percent in the low density stratum (figs. 3 and 4). Transect spacing varied by survey area according to expected sea otter densities and logistical constraints (table 2).

Aerial Survey Methods

For all three surveys, we used a Bellanca Scout, a two-passenger tandem, float-equipped, single-engine airplane, which allowed equal visibility out both sides of the aircraft. Survey conditions were generally limited to periods with wind velocities less than 18–28 km/h and sea conditions without whitecaps. Along each 400-m wide transect strip we recorded the number of individual sea otters observed and mapped their location. Intensive search units (ISUs) were used to estimate the proportion of animals that remained undetected during the strip counts. Detailed survey methodology is available in Bodkin and Udevitz (1999).

Data Analysis

Detection adjusted strip counts were used to calculate population estimates for each stratum sampled, and those were combined to provide population size estimates and associated sample variance estimates. Independent rates of population change over time were estimated for each of the three regions, and for SE AK as a whole, from the exponential function, $N_t = N_0 e^{rt}$, where N_t = population estimate in year t , N_0 = population estimate in some earlier year 0, and r = annual rate of increase (Estes, 1990). A linear regression was fitted to log-transformed values using PROC GLM in SAS 9.1 (SAS Institute, Cary, N.C.) for the relatively limited

time span (1999–2002) over which aerial surveys were conducted in Glacier Bay. A non-linear regression was fitted to the exponential model with the least-squares (Marquardt) method using PROC NLIN in SAS for the more extended period (1969–94) of population growth recorded for SE AK as a whole. Because ISUs also afford the aerial observer enough time to differentiate pups from independent (non-pup) otters, the pup:independent ratio was used as an index of reproduction for each area.

Aerial Survey Results

The surveys were conducted over a 2-year period because of the size and shoreline complexity of the area involved. The surveys for Glacier Bay (fig. 2) and for northern SE AK, from Icy Point to Cape Ommaney, were conducted in 2002 (fig. 3). The survey for southern SE AK, from Kake to Cape Chacon, was conducted in 2003 (fig. 4). Because about 80 km of unoccupied habitat separates the northern and southern SE AK survey regions, little, if any, movement of individuals between years was expected to influence the survey results, which are summarized below.

Glacier Bay

The survey of Glacier Bay was conducted between May 6 and 18, 2002. Replicate surveys took between 6 and 8 hours to fly and ranged from 297 to 343 km in total transect length. Five replicate surveys yielded a population size estimate of 1,266 sea otters (SE = 196; table 2; fig. 5). The density of sea otters in the surveyed portion of Glacier Bay was 2.3/km² and the pup:independent ratio was 0.14.

Northern Southeast Alaska

The survey of northern SE AK was conducted between June 30 and July 13, 2002. This survey was based at Bartlett Cove in Glacier Bay for transects north of Khaz Bay and at Sitka to access areas south of Khaz Bay. It took about 56 hours of flight time to survey 2,148 km of transect. Weather conditions greatly affected how many hours per day we flew on 11 survey days (range = 0.6 to 8 hrs/d) and precluded surveying on 3 days. Upon completion of the northern SE AK survey, survey area boundaries were adjusted to reflect sea otter distribution during the survey and accurately estimate sea otter densities (fig. 6). The 2002 population size estimate for northern SE AK was 1,838 sea otters (SE = 307, table 2). The density of sea otters in northern SE AK was 0.48/km² and the pup:independent ratio was 0.22.

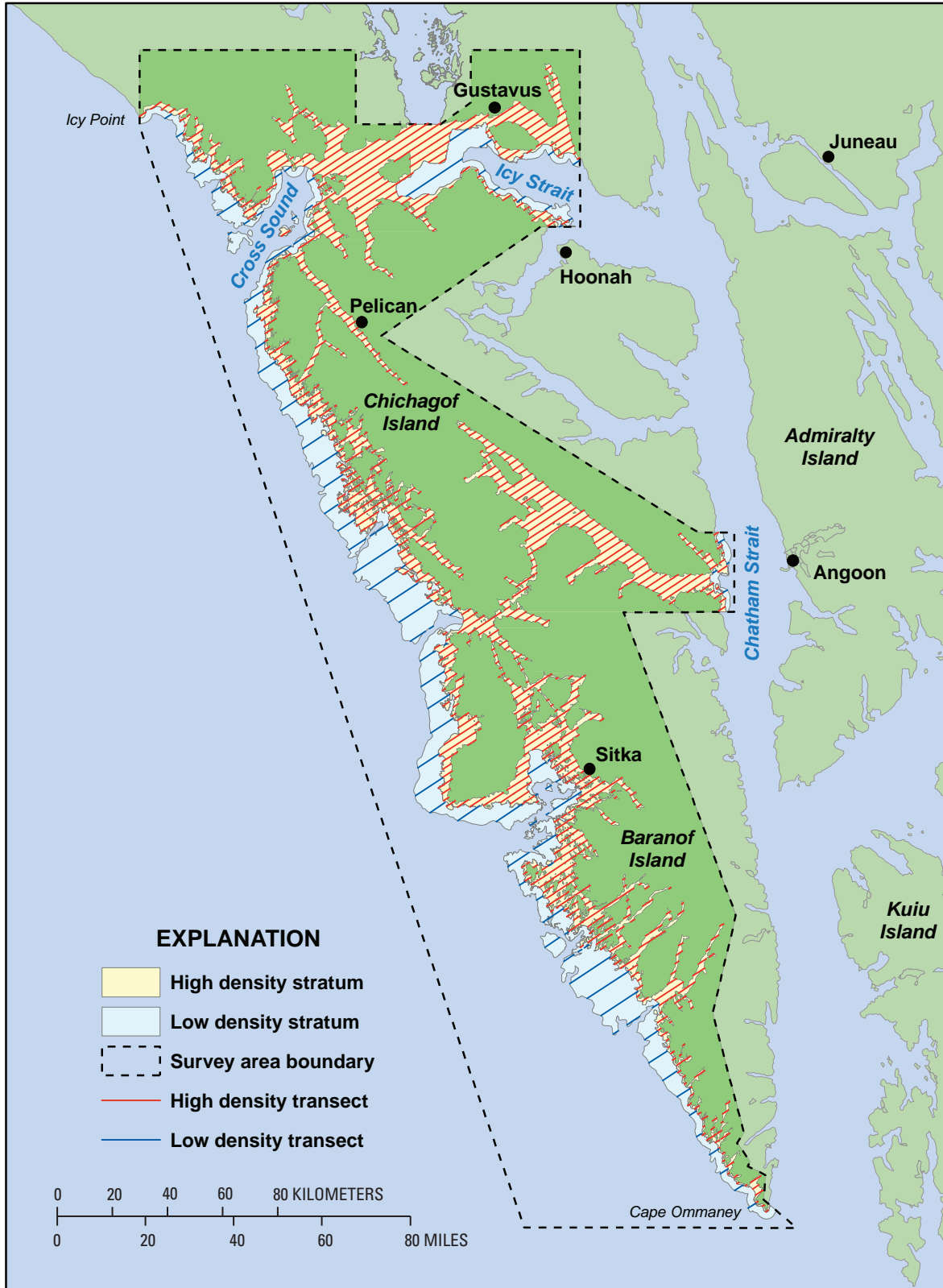


Figure 3. Aerial transects used for sea otter survey in northern Southeast Alaska, July 2002.

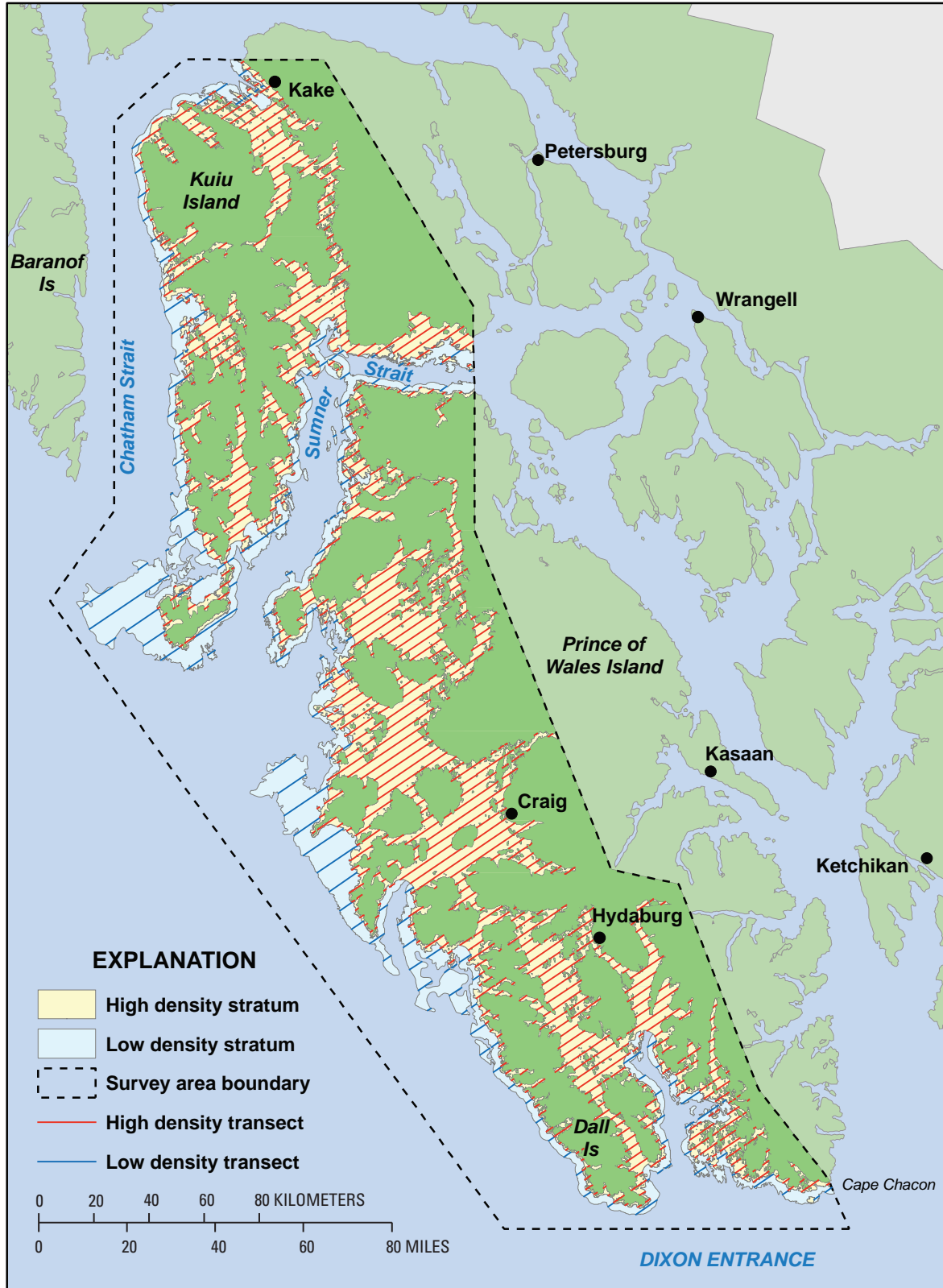


Figure 4. Aerial transects used for sea otter survey in southern Southeast Alaska, August 2003.

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Table 2. Southeast Alaska sea otter population estimates derived from aerial surveys conducted in 2002 and 2003.

[Stratum refers to stratification of sea otter habitat into areas of high and low sampling effort. The Glacier Bay population estimate was derived from five replicate surveys, whereas, northern and southern Southeast Alaska (SE AK) population estimates were derived from single surveys. Small groups (<30 sea otters) were adjusted with a correction factor, whereas, large groups were unadjusted. **Abbreviations:** m, meter; km, kilometer; km², square kilometer; <, less than]

Aerial survey year	Region	Stratum	Group size	Transect		Area sampled (km ²)	Stratum area (km ²)	Sea otter count	Correction factor	Corrected population size	Standard error	Proportional standard error
				Spacing (m)	Sampled (km)							
2002	Glacier Bay	High – replicate 1	Small	1,200	226	90	272	98	1.60	472	–	–
		High – replicate 2	Small	1,200	228	91	272	73	1.75	381	–	–
		High – replicate 3	Small	1,200	229	92	272	72	1.38	294	–	–
		High – replicate 4	Small	1,200	202	81	272	84	1.44	408	–	–
		High – replicate 5	Small	1,200	214	86	272	58	1.36	250	–	–
		Low – replicate 1	Small	2,400	111	44	277	43	1.60	432	–	–
		Low – replicate 2	Small	2,400	111	44	277	21	1.75	230	–	–
		Low – replicate 3	Small	2,400	114	45	277	23	1.38	193	–	–
		Low – replicate 4	Small	2,400	96	38	277	22	1.44	230	–	–
		Low – replicate 5	Small	2,400	113	45	277	20	1.36	166	–	–
	High – replicate 1	Large	1,200	226	90	272	158	–	476	–	–	
	High – replicate 2	Large	1,200	228	91	272	298	–	890	–	–	
	High – replicate 3	Large	1,200	229	92	272	175	–	521	–	–	
	High – replicate 4	Large	1,200	202	81	272	188	–	635	–	–	
	High – replicate 5	Large	1,200	214	86	272	63	–	200	–	–	
	Low – replicate 1	Large	2,400	111	44	277	28	–	176	–	–	
	Low – replicate 2	Large	2,400	111	44	277	21	–	132	–	–	
	Low – replicate 3	Large	2,400	114	45	277	0	–	0	–	–	
	Low – replicate 4	Large	2,400	96	38	277	34	–	247	–	–	
	Low – replicate 5	Large	2,400	113	45	277	0	–	0	–	–	
										1,266	196	0.15
2002	Northern SEAK ¹	High	Small	1,500	1,407	563	2,089	297	1.16	1,282	182	0.14
		Low	Small	5,000	325	130	1,732	4	1.16	62	36	0.58
		High	Large	1,500	1,407	563	2,089	133	–	494	245	0.50
										1,838	307	0.17
2003	Southern SEAK ¹	High	Small	2,000	1,729	692	3,418	473	1.69	3,958	590	0.15
		Low	Small	5,000	305	122	1,902	8	1.69	211	97	0.46
		High	Large	2,000	1,729	692	3,418	339	–	1,675	564	0.34
										5,845	821	0.14
Southeast Alaska										8,949	899	0.10

¹Numbers for this region are derived from high and low density strata that were reduced post-survey to reflect actual sea otter distribution during the survey.

Southern Southeast Alaska

The southern SE AK survey, conducted between July 31 and August 12, 2003, included 2,640 km of transect in 77 hours of flight time. Although predominately sunny weather permitted surveying on 12 of 13 days, windy conditions greatly limited survey time on most days (range = 1.5 to 8 hrs/d). The survey area was reduced post-survey to closely match actual sea otter distribution and ensure accurate otter density estimation (fig. 7). The 2003 southern SE AK

population was estimated to be 5,845 sea otters (SE = 821, table 2). The density of sea otters in southern SE AK was 1.01/km² and the pup:independent ratio was 0.26.

Southeast Alaska

Based on these three surveys, the estimated population of otters for the entire region in 2002–03 was 8,949 (SE = 899), at a density of 0.92 individuals/km².

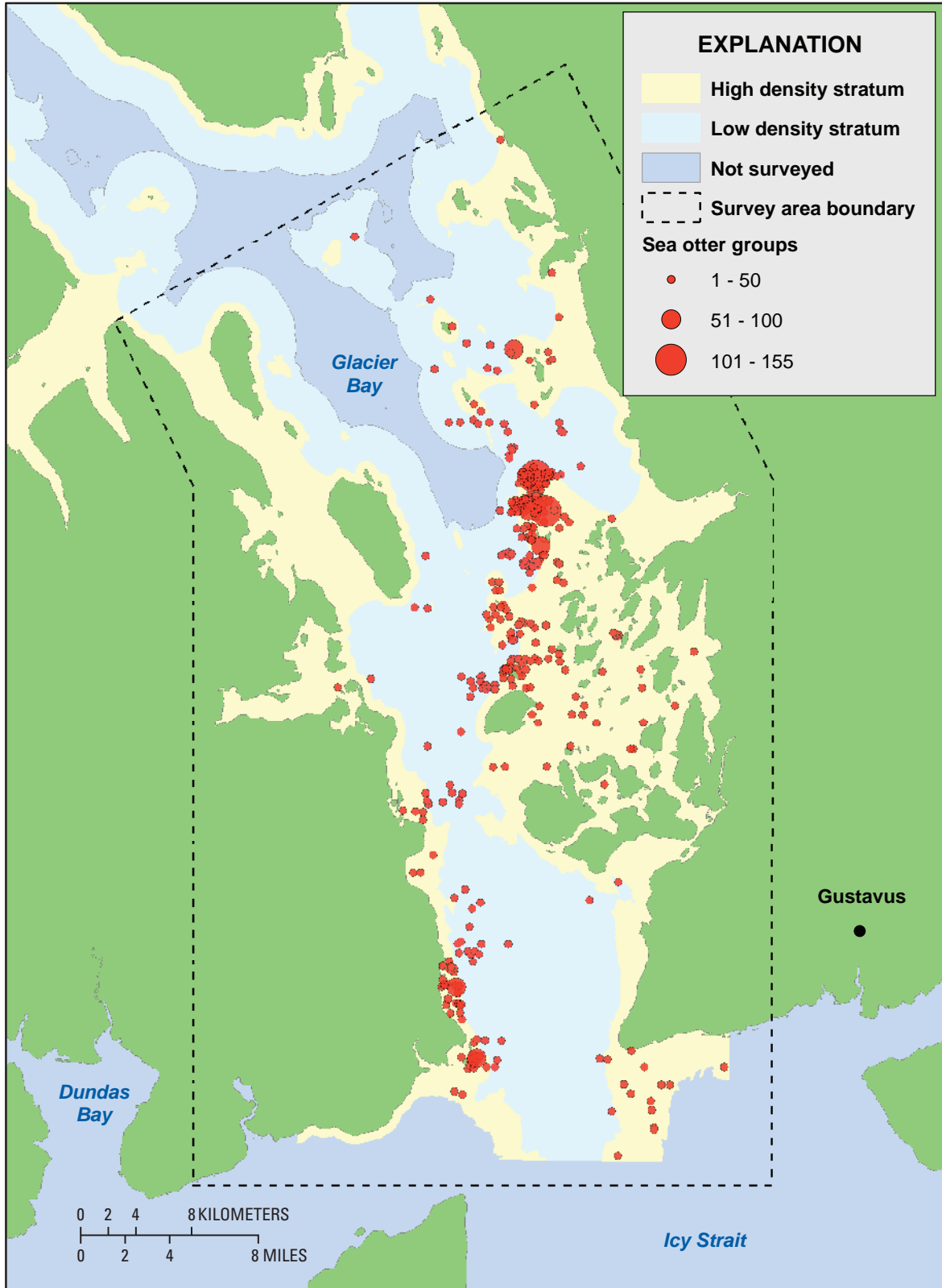


Figure 5. Cumulative distributions of sea otter groups from five replicate aerial surveys in Glacier Bay, Alaska, May 2002. (See [figure 2.](#))

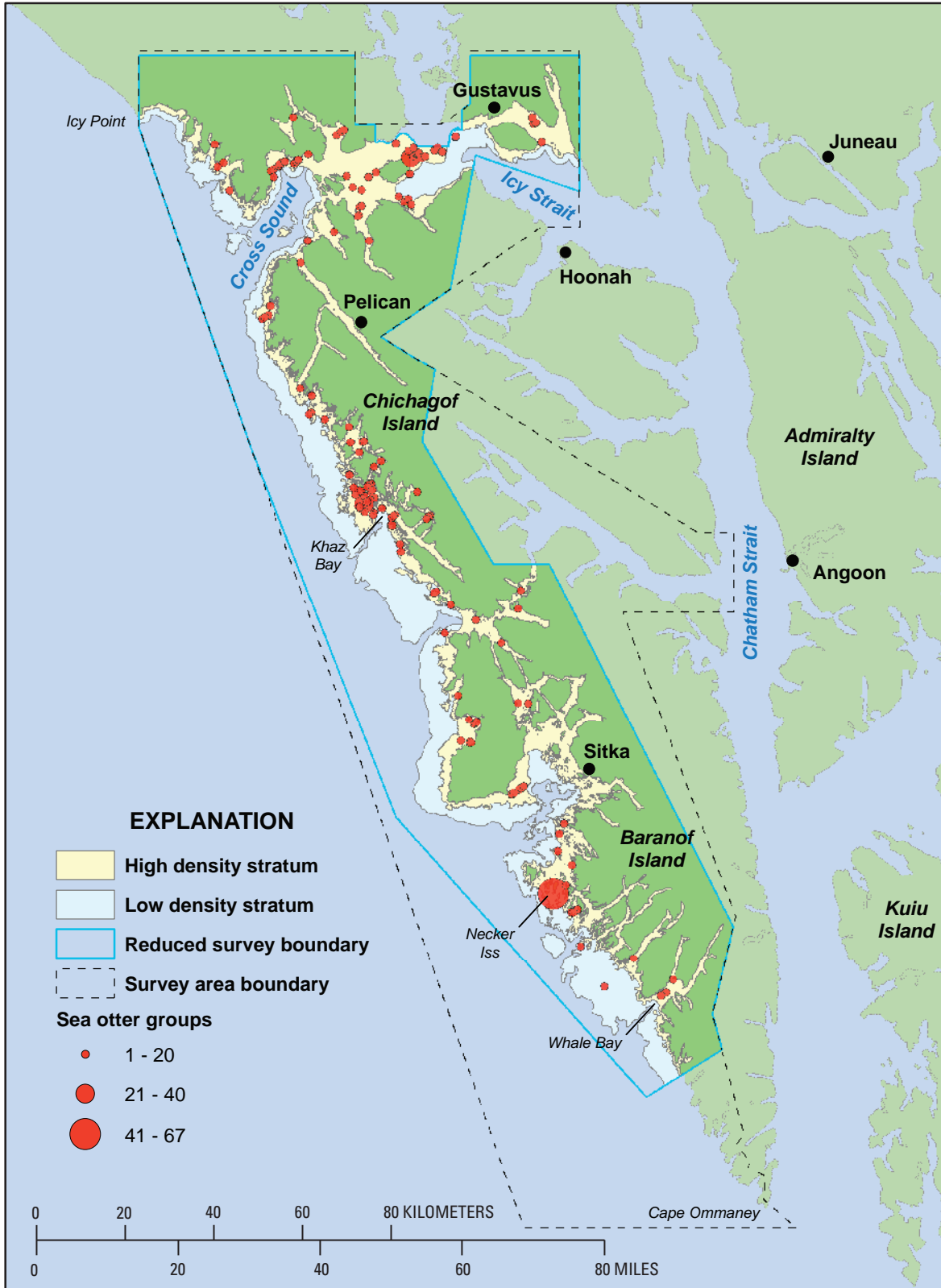


Figure 6. Sea otter group locations from aerial survey in northern Southeast Alaska, July 2002. Also shown are strata that have been reduced from the area surveyed to reflect sea otter distribution and estimate abundance (see [figure 3](#)).

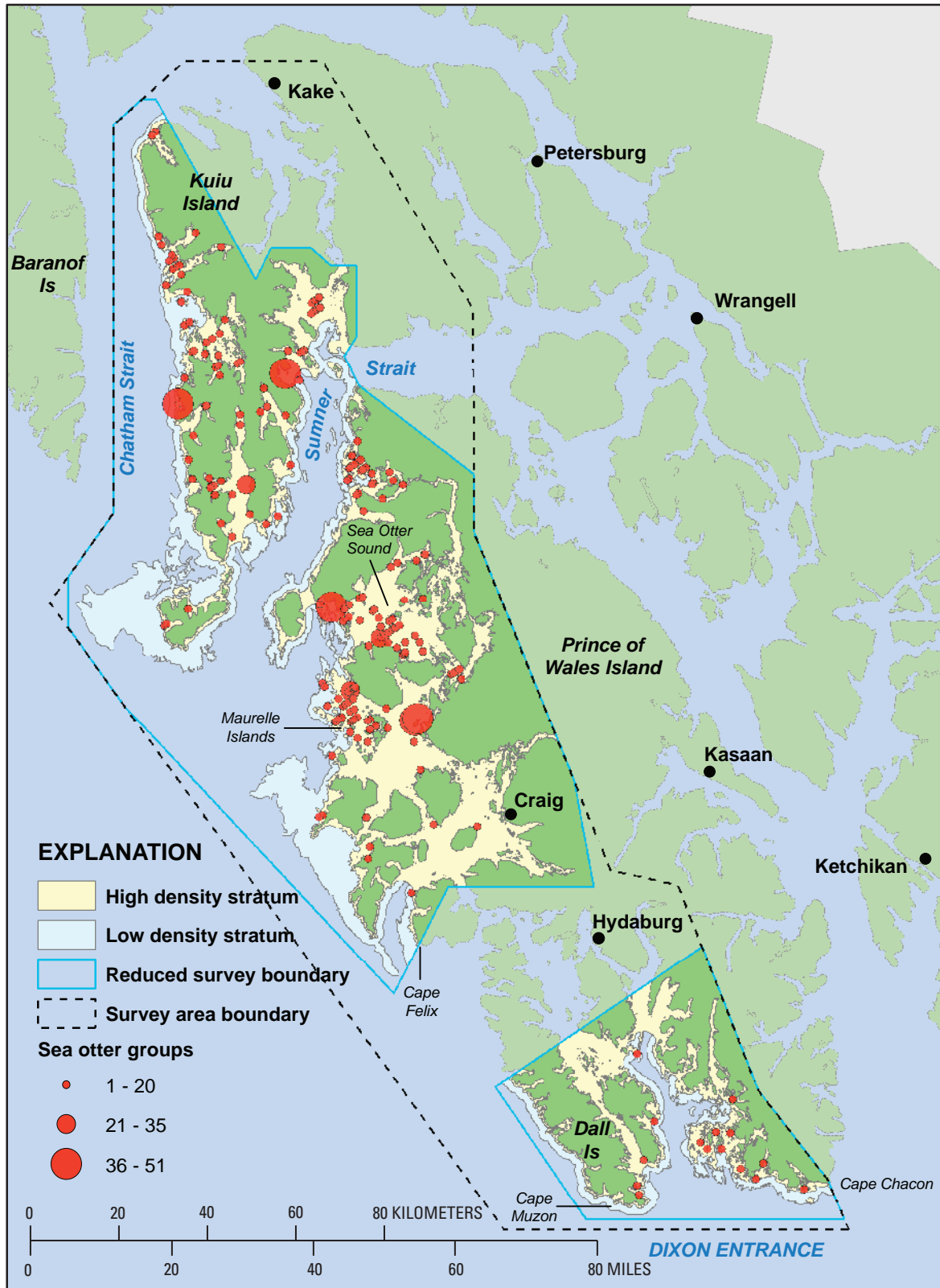


Figure 7. Sea otter group locations from aerial survey in southern Southeast Alaska, August 2003. Also shown are strata that have been reduced from the area surveyed to reflect sea otter distribution and estimate abundance (see [figure 4](#)).

Status and Trends in Sea Otter Populations

Sea otter populations can be described on the basis of two characteristics: distribution, or their spatial occurrence and extent of their range; and abundance, the actual numbers and trends in numbers of otters present.

Distribution

The results of the 2002–03 aerial surveys indicate that sea otters in SE Alaska were not evenly distributed across the region, but generally occurred in three spatially discrete sub-populations: (1) the northern population, (2) the Maurelle population, and (3) the Barrier population (fig. 8). The scarcity of otters in areas between these three concentrations was likely a historical consequence of commercial fur harvests and translocations, but also probably reflected limited dispersal between these areas.

Northern Population

The northern sea otter population extended along the outer coast from Icy Point in the north to Whale Bay in the south (fig. 8). Increases in abundance and changes in distribution had occurred since Pitcher's 1987 survey (Pitcher, 1989), with population expansion north into Glacier Bay and south to Whale Bay.

Maurelle Population

An 80 km gap between Whale Bay and Kuiu Island separated the northern population from the Maurelle population (fig. 8). Since Pitcher's 1988 survey (Pitcher, 1989), the Maurelle population had expanded northward, up the western side of Kuiu Island, further into Sumner Strait, and Sea Otter Sound. On the southern end of this population, sea otters expanded from the Maurelle Islands southward to Cape Felix (fig. 7).

Barrier Population

The Maurelle population and the Barrier population were separated by a 75 km gap between Cape Felix and Cape Muzon (fig. 7). In contrast to the other two SE AK populations, the Barrier population expanded its distribution only slightly since 1988 (Pitcher, 1989).

Southeast Alaska Distribution

The historical range of sea otters in SE AK included the outer coast, but the extent to which otters occupied inside waters is not well known. Kenyon (1969, p. 183) states,

“There is no record that sea otters occurred in the inland passages of Southeastern Alaska . . .” and Kvittek and others (1991) suggested that paralytic shellfish poisoning toxins sequestered by butter clams (*Saxidomus giganteus*), an important sea otter prey, may limit sea otter distribution to the exposed outer coast of SE AK. Pitcher (1989), however, pointed out that sea otters occur in the inside waters of Prince William Sound, an area with habitat qualities similar to those of the inside waters of SE AK. Sea otter bones excavated from aboriginal Tlingit middens at Daxatkanada, Young Bay, and Port Houghton (fig. 8) indicate sea otters were a human food source that may have been obtained locally from inside waters (de Laguna, 1960; Swanson and Davis, 1982; Davis, 1985).

Sea otters have become well established in some inside waters such as Glacier Bay and Sumner Strait (fig. 8). This inside range expansion is a significant development because it demonstrates that sea otters are capable of colonizing inside waters in SE AK and are likely to extend their distribution into other inside waters in the future.

Abundance

Comparisons of the results of our 2002–03 surveys of otter populations in Southeast Alaska with those of earlier surveys show that population growth trends differ across the three survey areas. These differences can be explained, at least in part, by several factors that potentially control population growth.

Glacier Bay and Northern Southeast Alaska

The lower (southern) part of Glacier Bay currently supports some of the highest sea otter densities ever recorded in SE AK. Studies in this region have documented the dramatic increase from 5 otters in 1995 to 1,266 in 2002 (fig. 9; J. Bodkin, U.S. Geological Survey, written commun., 2003). Although Glacier Bay sea otters are not completely isolated from nearby populations in Icy Strait and Cross Sound (fig. 6), the population trajectories in Glacier Bay differ dramatically from trajectories elsewhere in SE AK and warrant independent evaluation. The annual rate of increase for sea otters within Glacier Bay has been 44 percent per year since systematic aerial surveys were implemented in 1999. Because this rate of increase exceeds the reproductive capacity of the species (Estes, 1990), it is reasonable to conclude that immigration is contributing to the high growth trend in Glacier Bay. In contrast to the rapid increase in Glacier Bay alone, the combined 2002 population size estimate for Glacier Bay and northern SE AK (3,104) is only 35 percent greater than Pitcher's 1987 count (2,295; Pitcher, 1989), indicating relatively slow population growth overall (2.0 percent per year) for this period (fig. 10). This is in contrast to the previously documented growth rate for SE AK of 18 percent per year between 1975 and 1987 (Estes, 1990).

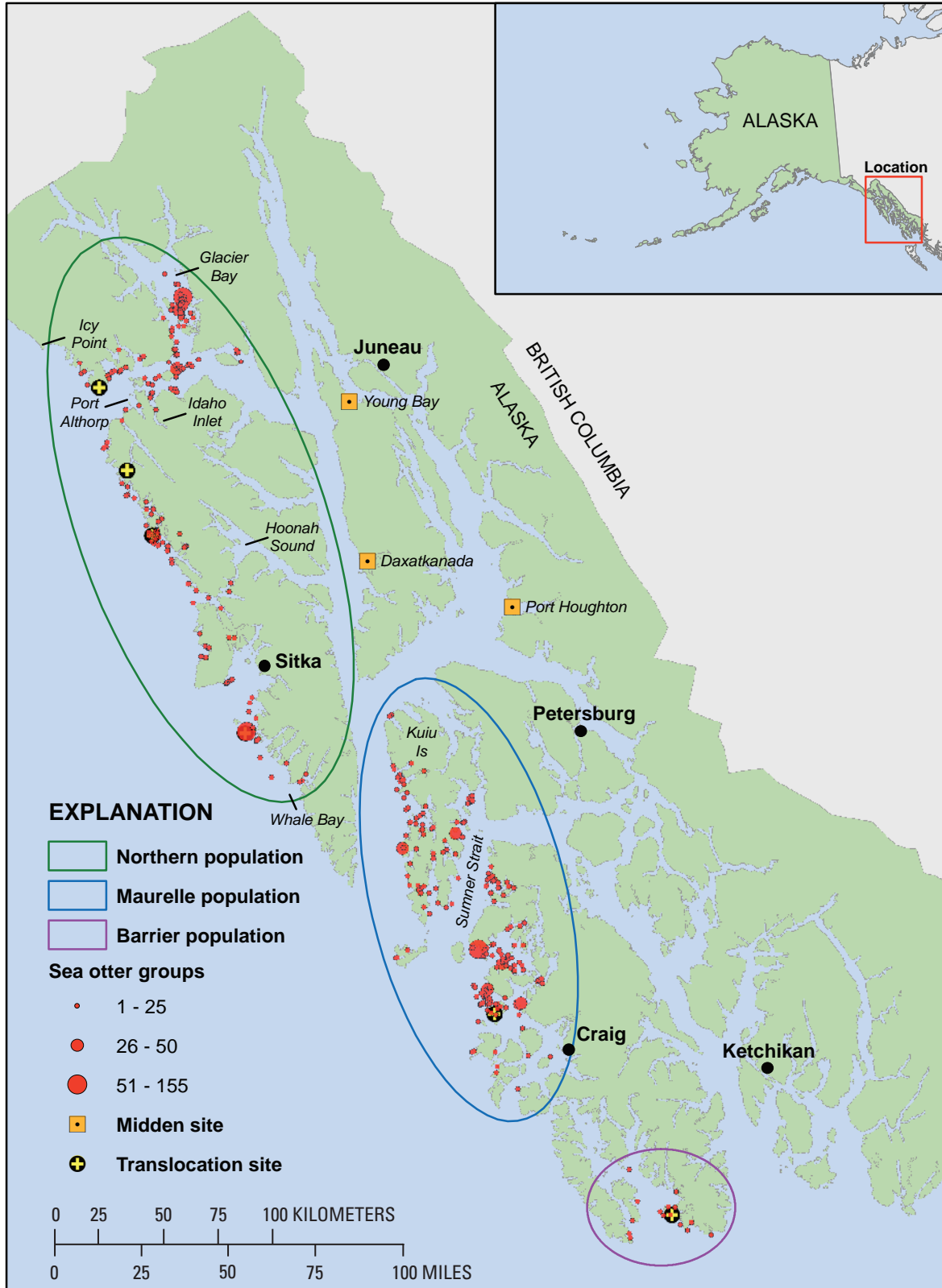


Figure 8. Sea otter distribution from aerial surveys in Southeast Alaska (SE AK), summers 2002, 2003. Maurelle and Barrier populations were treated as one population (southern SE AK) for trend analysis. Midden sites containing sea otter bones indicate potential historical distribution.

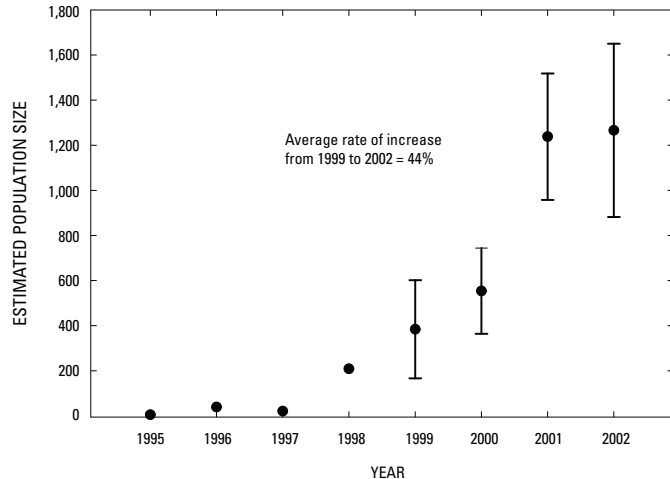


Figure 9. Trends in abundance of sea otters in Glacier Bay National Park and Preserve, Alaska, 1995–2002. (J. Bodkin, U.S. Geological Survey, written commun., 2003.) Error bars represent 95 percent confidence intervals.

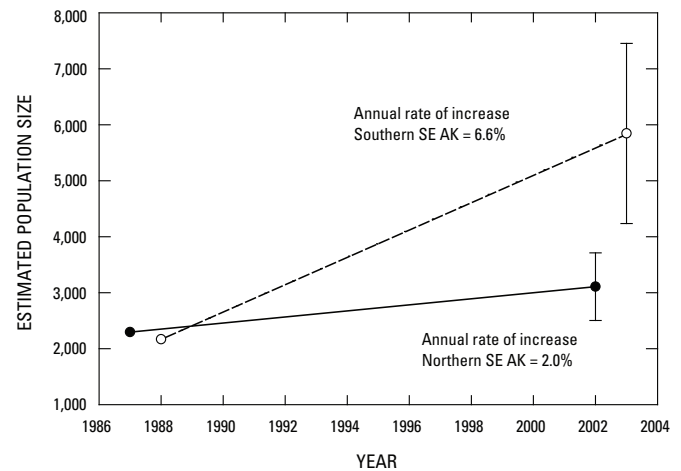


Figure 10. Sea otter population trends in northern and southern Southeast Alaska (SE AK), 1987–2003, inclusive of Glacier Bay and all other occupied habitats. Count data for 1987 and 1988 are from Pitcher (1989). See [figure 11](#) for data prior to 1988. Error bars represent 95 percent confidence intervals.

Southern Southeast Alaska

Although the Maurelle and Barrier populations were spatially distinct, the data were combined for the analysis of sea otter population growth in southern SE AK because the Barrier Island population was too small to provide an independent estimate of abundance given the sampling design used. The abundance of sea otters within the southern SE AK survey area had increased at an annual rate of 6.6 percent since Pitcher's 1988 count of 2,167 (Pitcher, 1989) ([fig. 10](#)). Although this rate is more than 3 times greater than the rate observed in northern SE AK, it is less than one-half of the 14 percent annual growth observed between 1969 and 1994 ([fig. 11](#)).

Southeast Alaska

In 1994, Agler and others (1995) conducted a boat-based systematic survey of all marine waters in SE AK to estimate populations of marine birds and mammals. Their survey differed from Pitcher's (1989) surveys in that Agler and others counted all marine birds and mammals and systematically sampled a small proportion (less than 3 percent) of all habitat, whereas Pitcher counted only sea otters, surveyed only occupied sea otter habitat, and attempted to census the population (with no correction). Because Agler and others included all of SE AK and their sampling effort was low, incorporating these data required treating SE AK as a single geographic unit. However, because Agler and others sampled

such a small proportion of sea otter habitat, and because their survey area included more unoccupied than occupied habitat, we have relatively less confidence in the accuracy of their sea otter population estimate of 8,180 (95 percent confidence interval = 1,894–14,466). Nonetheless, no other estimates of SE AK sea otter population size were made between 1988 and 2003.

Another limitation of the 1994 population estimate from Agler and others (1995) is that it does not include a correction factor to account for undetected otters. Udevitz and others (1995) estimated that 30 percent of the sea otters present along surveyed transects were not detected during a survey using similar methods conducted in Prince William Sound, Alaska. Trends in sea otter abundance in SE AK since 1969, including the uncorrected estimates from Agler and others (1995), suggest a population rapidly increasing at an annual rate of 14 percent through 1994 ([fig. 11](#)). To allow comparability with our detection-adjusted 2003 estimate, a correction factor was applied to the Agler and others (1995) estimate. The correction factor was based (conservatively) on the 70 percent detection rate estimated by Udevitz and others (1995); based on the corrected estimate, the SE AK population apparently declined at an annual rate of -3 percent between 1994 and 2003 ([fig. 11](#)).

In the absence of the 1994 data (Agler and others, 1995), estimates of population growth rates for sea otters in SE AK between 1987 and 2003 (2.0–6.6 percent per year) are substantially lower than rates reported in earlier studies, which range from 15.7 to 23.3 percent per year (Pitcher, 1989; Estes, 1990; Bodkin and others, 1999). Further, for any

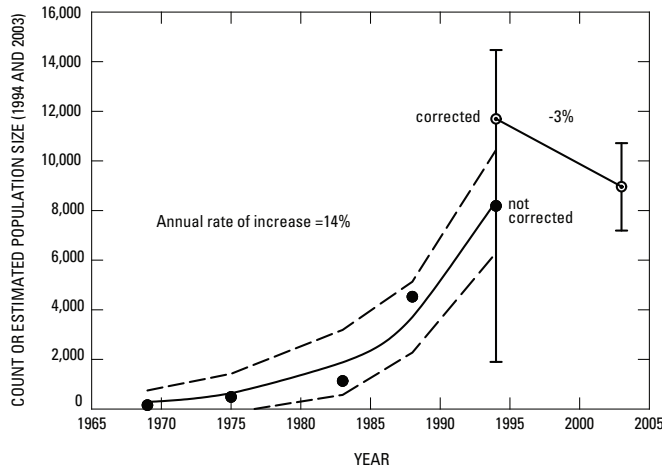


Figure 11. Trends in sea otter populations in Southeast Alaska between 1969 and 2003. (1969, Estes and others, 1989; 1975, Schneider, 1975; 1983, Johnson and others, 1983; 1988, Pitcher, 1989; 1994, Agler and others, 1995; 2003, this study.) The 1994 estimate was not corrected for detection when calculating the growth rate from 1969–94, but was corrected using a 70 percent detection rate (Udevitz and others, 1995) to calculate a rate of change from 1994–2003. Dashed curves approximate a 95 percent confidence interval for the expected values associated with the 1969–94 regression line. Error bars indicate 95 percent confidence intervals and are associated only with the “not-corrected” estimate in 1994.

recovering population (Estes, 1990; Bodkin and others, 1999), the growth rates reported here are among the lowest, including those reported for California (4.4–7.8 percent per year; Estes, 1990). The inclusion of the 1994 survey results does not modify the finding of a reduced rate of change in the SE AK sea otter population, but it does influence our understanding of the magnitude of the change. When the 1994 uncorrected estimate is included in the trend analysis, the emergent pattern is one of continued increase in growth rates through the mid 1990s, followed by a period of apparent stability. Although population growth of sea otters would be expected to reach an asymptote as population size approaches carrying capacity, the reduced growth rate and the decline were unanticipated given the amount of unoccupied habitat available in SE AK and the continued growth observed in the Glacier Bay population.

Potential Factors Limiting Population Growth

Ultimately, sea otter population growth in SE AK is being limited by one or more of the following population processes: reproduction, emigration, or mortality. Reproduction, estimated by the proportion of pups (to total number of individuals) detected in ISUs, ranged from 0.14 to 0.26 and

is consistent with growing populations elsewhere (Estes, 1990; Riedman and Estes, 1990). Rates of emigration to SE AK are difficult to assess, but is likely insignificant given what is known about the magnitude and frequency of sea otter movements and the extreme distances required for emigration to other populations (Kenyon, 1969; Riedman and Estes, 1990). That leaves mortality as the process most likely responsible for reduced, or negative, population growth.

Possible factors contributing to mortality include lack of food, pollution (or other habitat degradation), disease, predation, and direct human-caused mortality (boat strikes, legal and illegal take). Our own studies in Port Althorp, Idaho Inlet, and Glacier Bay, in northern SE AK (fig. 8) suggest that food may be a limiting resource in areas of long-term occupation by sea otters, but recently occupied or unoccupied areas tend to have abundant prey resources (Bodkin and others, 2007). High densities of sea otters in newly occupied areas seem to support this observation, and because the majority of sea otters in SE AK now live in such areas, we would expect food to be limiting for a relatively small proportion of the population. Significant levels of mortality resulting from starvation, pollution or disease are usually accompanied by observations of moribund animals or large numbers of carcasses (Bodkin and others, 2000; Ballachey and others, 2002), but no such reports of “die-offs” have been documented in SE AK.

Killer whale (*Orcinus orca*) predation has been cited as the major cause of recent sea otter declines in the Aleutian archipelago (Estes and others, 1998; Doroff and others, 2003), but this predation does not appear to be a limiting factor in SE AK for three reasons. First, even though SE AK has higher densities of potential human observers when compared to the Aleutians, we are not aware of any confirmed sightings of killer whales consuming sea otters in SE AK (Straley and Trites, 2005). Second, mammal-eating killer whales are thought to have increased sea otter depredation in the Aleutians because preferred prey populations of harbor seals (*Phoca vitulina*) and Steller sea lions (*Eumetopias jubatus*) had been significantly depressed in that region (Estes and others, 1998). With few exceptions, SE AK pinniped populations appear healthy and generally increasing in abundance (Calkins and others, 1999; National Research Council, 2003; Small and others, 2003). Third, for killer whale predation to be a significant source of mortality in SE AK, such predation would need to be spatially “patchy” (for example, restricted to areas outside of Glacier Bay, where increases in abundance exceed theoretical limits), a pattern not consistent with the broad geographic ranges of transient killer whales (Goley and Straley, 1994), and in contrast with the spatially uniform declines associated with killer whale predation in Southwest Alaska. Depredation by other potential predators, including sharks or terrestrial carnivores (Riedman and Estes, 1990), cannot be ruled out as a source of mortality, but no evidence exists to implicate predation as a cause for reduced growth rates in Southeast Alaska sea otters.

Sea otters are harvested by legal subsistence hunting in most of Alaska. Hunters reported harvesting 2,311 sea otters from northern SE AK and 1,702 from southern SE AK between 1989 and 2003 (U.S. Fish and Wildlife Service, unpub. data, 2006). In the north, the average annual reported harvest was 154 animals (range 35 to 526). This represents a minimum annual harvest of 8 percent of the estimated 1,838 sea otters outside of Glacier Bay National Park and Preserve, where no hunting is permitted. In the north, 30 percent of the reported harvest was female and 70 percent was male. In the south, the average annual reported harvest was 121 animals (range 10 to 277). This represents a minimum annual harvest rate of about 2 percent of the southern population, and 34 percent of this reported harvest was female and 66 percent was male.

Samuel and Foin (1983) used a Leslie matrix population model to explore a range of harvest rates for Alaskan sea otters. With a series of 25-year simulations, they determined that 2–4 percent harvest rates are sustainable, but that 8–10 percent harvest rates result in continual population declines. However, because their model constrained average annual population growth to 4.6 percent, rates of change less than this would require reduced harvests to attain stability in population size. It would therefore seem that pre-existing harvest levels may have been sufficient to limit population growth in some regions of SE AK, particularly in the north. Because we have no estimates of illegal harvesting, this conclusion is likely conservative. The recent availability of age- and sex-specific fecundity and survival rates could be used to develop age- and sex-structured population matrix models (Caswell, 2001) and better understand the potential impact of hunting under a variety of specific population growth and harvest scenarios.

Conclusion

Southeast Alaska supports a relatively large and geographically isolated sea otter population resulting from multiple translocations nearly 30 years ago. Discontinuities in the present-day distribution appear to reflect range expansion over time from the translocation sites along outer coast habitats. Colonization of new habitat includes inside waters greater than 75 kilometers from the outer coasts. Population growth rates appear divergent among areas and lower than historical post-translocation rates, with the exception of Glacier Bay, where unprecedented growth is resulting from immigration and reproduction. Causes of reduced population growth outside of Glacier Bay are uncertain, but hunting appears to be a substantial cause of mortality. Development of age- and sex-structured population models, which would incorporate the estimates of rates of population change reported here as well as recently available data on age- and sex-specific fecundity and survival rates, would help guide the management and conservation of sea otter populations in Southeast Alaska.

Acknowledgments

Support for this project was provided by the U.S. Geological Survey Alaska Science Center, U.S. Fish and Wildlife Service Marine Mammals Management, and Glacier Bay National Park and Preserve. We thank Patrick Kearney (Cordova Air Service) for safely piloting the surveys, Heather Coletti (USGS) for helping to digitize bathymetry, and the following for their contributions to the survey: Janet Doherty (NPS), Angela Doroff (USFWS), John Haddix (USFWS), Jack Hodges (USFWS), Rikk Kvitek (California State University Monterey Bay), Mike Miller, the Alaska Sea Otter and Steller Sea Lion Commission, and the Sitka Marine Mammal Commission. We also thank the U.S. Forest Service in Craig, Alaska, for providing lodging and logistical support. Tony DeGange, Gary Drew, Kim Kloecker, Dan Monson, Karen Oakley, Tim Tinker, and Mark Udevitz provided helpful comments on earlier drafts of this report.

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Publishing support provided by the U.S. Geological Survey
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